Lasing Modes in a Spiral-Shaped Microcavity

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Abstract

Lasing modes in a two-dimensional spiral-shaped microcavity are numerically studied in a nonlinear dynamical model, Schrödinger-Bloch model. The stationary lasing mode of the model is analyzed by comparing to the resonances in the corresponding passive cavity. We also investigate the quasiscarring patterns when a selective pumping is applied. We discuss the dynamical behavior of electric field intensity during the transient in the nonlinear dynamical model.

Recently there is a remarkable experimental report which has successfully shown unidirectional emission in microlasers [1]. For the unidirectional emission, they designed spiral-shaped quantum-well microlasers with given boundary geometry $r(\phi) = R(1 + \frac{\epsilon}{2\pi})$, where R is the radius of the spiral at $\phi = 0$ and ϵ is the deformation parameter. The unidirectionality originated from the special properties of the spiral-shaped boundary geometry, i.e., the absence of any symmetry and the existence of the notch, and the fully chaotic ray dynamical property of this boundary shape cavity. Another remarkable property of this spiral-shaped microcavity is reported by Lee *el al.*, existence of quasiscarred resonances [2]. The quasiscarred resonance has strongly localized pattern which are not supported by any unstable periodic orbit. The existence of quasiscarred resonances implies that the scarring phenomenon in dielectric microcavities has substantial differences from the conventional scarring in billiard systems, due to the inherent characteristics of dielectric cavities.

In this study, we investigate the lasing patterns in the spiral-shaped dielectric microcavity. We find some strongly localized lasing patterns and we compare this numerical results with passive resonance modes. To investigate the lasing mode in this microcavity, we apply the Schrödinger-Bloch model, which was introduced by Harayama *et al.* [3]. We also find some resonance patterns in a given nkR range, using the boundary element method(BEM) [4]. For convenience, we take $\epsilon = 0.1$ and $R = 1$ in this study.

Figure 1(a) shows a triangle-shaped quasiscarred resonance obtained around $Re[nkR] \approx 30$ by the BEM. We can also find whispering gallery mode(WGM) like resonances around this nkR value. When we apply the uniform external pumping rate(W_∞) over the whole cavity in the Schrödinger-Bloch model, the WGM like lasing mode is dominant. However, if we apply W_∞ selectively such as Fig. 1(c), we can find the quasiscarred lasing mode (Fig. 1(b)) corresponding to the passive cavity mode. The difference of angles between triangle shapes in lasing mode and pumping region, and the chirality of the emission beam show

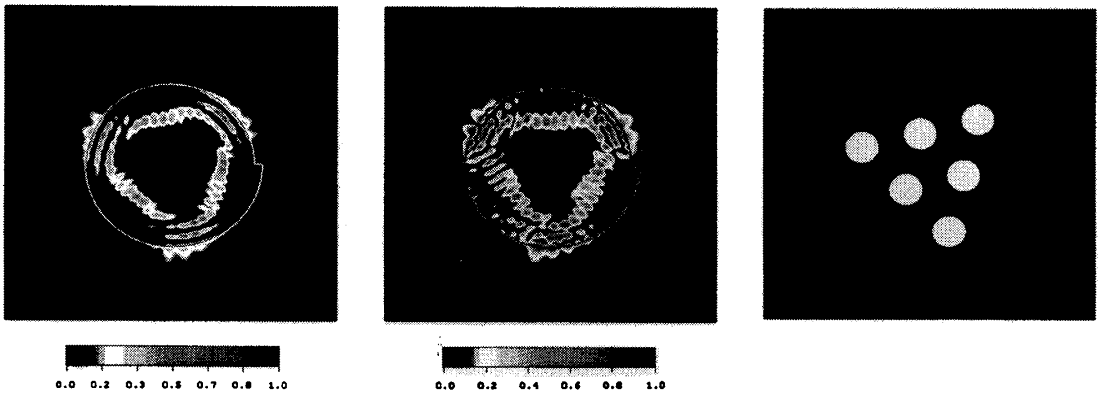

Figure 1: (a) Field intensity plot of quasiscarred resonance in the passive cavity for $n = 2$ and $nkR \approx (29.9, -0.12)$. (b) Field intensity plot of lasing pattern using Schrödinger-Bloch model for $n = 2$ and $Re[nkR] = 30$. In figures (a) and (b), the field intensity is normalized by scaling the maximum intensity as 1. (c) Geometrical shape of selected external pumping region (white circles).

that this quasiscarred resonance is not an artificial effect of selective pumping. From the time series and power spectrum analysis of electric field amplitude at a selected point inside the cavity, we find that this lasing mode is stationary multi-mode. We also have found star-shaped quasiscarred lasing mode for the refractive index $n = 3$ case (not shown here).

In conclusion, we have investigated the lasing modes in a spiral-shaped microcavity. WGM mode is dominant when the external pumping is applied uniformly. Quasiscarred resonance mode can be lased when selective pumping is applied with some spatial geometry. This implies that we can lower the lasing threshold and lase a good directional emission, if we choose proper selective pumping region.

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